Operational Experience with the AMS/IB System

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Objective of This Presentation

- **Describe the insights into operation of the AMS/IB, including problems and solutions, that have been gained during system fabrication and testing; and**
- **in so doing, simplify the cooperative development of a subsequent system.**

Types of Issues

- Information barrier issues
- Physics issues
- Electronics issues
- Computer issues
- Issues involving operations with nuclear materials

Information Barrier (IB) Issues

Without exception,

on all occasions when the AMS/IB was used

to perform a measurement in its secure mode,

the AMS/IB was successful

in preventing the display of sensitive information.

This is the most important point in this presentation.

Physics Issues

- The relevant cross sections, energies and branching ratios are generally well known.
  - Exceptions: some cross sections that are associated with gamma production in oxide.
  - However: quantitative interpretation would be impossible anyway because of matrix effects.
  - Therefore: an empirical approach is used in the absence-of-oxide attribute.
- Challenges arise when applying fundamental physics information to the analysis of actual samples, which contain impurities, etc.

Example of a Physics Issue

- **The attribute we call "age" is more accurately described as "time elapsed since last chemical purification that frees the material of Am."**
  - **Time elapsed since <u>creation</u> of the plutonium cannot be determined without *a priori* knowledge (or declarations) of plutonium isotopics.**
  - **Time elapsed since <u>purification</u> can be measured using the ^{241}Pu daughter method, described in other talks.**
  - **Time elapsed since purification is always ≤ time since creation.**
- **This has been recognized in previous US–Russian Federation discussions (PPRA).**

Example of a Physics Issue—Continued

- The distinction does not pose a problem for Pu that was *created* recently—
- but it does give rise to a problem with material created many years ago but *separated* recently, because most of the ^{241}Pu has decayed away.
- The US has no stocks of plutonium created recently.
- Therefore the sample used to test the “age” algorithm contains Pu that was created many years ago but was chemically purified in 1999.
- This has caused problems in algorithm robustness that would not exist if the algorithm were applied to recently created plutonium.

Other Physics Issues

- Proper handling of differential attenuation for diverse sources.
- Pu600 robustness in the absence of Am (old Pu recently processed).
- Choosing a threshold for α based on realistic oxide samples.
- Origin of the 871-keV line in γ-ray spectra from oxide.

Research dealt successfully with all of these issues, but proved more time-consuming than originally anticipated.

Electronics Issues

The AMS/IB contains complex instruments, and its design, construction, and operation were constrained by the following:

- security (paramount consideration);
- project demands
  - the decision to use “off the shelf” elements where possible and minimize customized elements;
  - the schedule originally targeted a much earlier demonstration date; and
- authentication issues.

Electronics Failure Considerations

Because the instruments in the AMS/IB are relatively uncommon, less quantitative information concerning mean time between failures (MTBF) is available for them.

- Neutron detectors are very robust (MTBF > 10,000 hours)
- HPGe detectors are highly variable in their robustness:
  - an individual detector might fail in days or last for years;
  - performance might be degraded even when the detector seems to be adequately functional.
- The signal-processing electronics are moderately robust, but failures tend to be severe and diagnosis can be difficult, as the IB can complicate diagnostic procedures if the error occurs in the secure mode.

Strategies to Mitigate Failures

- Reliance upon off-the-shelf technology
- Spares and backups
- Frequent test runs to detect hardware failures as they occur

Note: frequent test runs are critically important because running diagnostics on the AMS/IB with the information barrier in place is difficult.

Computer Issues

- All software used in the detector analyzers is derived from software in widespread use in safeguards, etc.
- However, most such codes were designed to reveal, not conceal, information.
- Furthermore, the information-barrier emphasis on a simplified operating system, etc., runs contrary to state-of-the-art R&D (and operational) practice.
- Accordingly, extensive modifications to the analyzer software were necessary, complicating both computer development and debugging, as was the case with the system electronics.
- Diagnostics were difficult, as with the electronics.

Nuclear Materials Issues

- There are only a few places in the US where the necessary inventories of nuclear materials exist, and most are unsuitable for an R&D program.
- Much programmatic competition for time and resources at the development site.
- The materials themselves posed unexpected challenges:
  - only very small samples of “young” material were available; and
  - oxide samples had no fixed geometry and shifted when the samples were handled, complicating symmetry measurements.

Operating History 1 Dec 99 – 15 Feb 00 (Authentication Sources)

Instrument underwent checkout and frequent modification during this period.

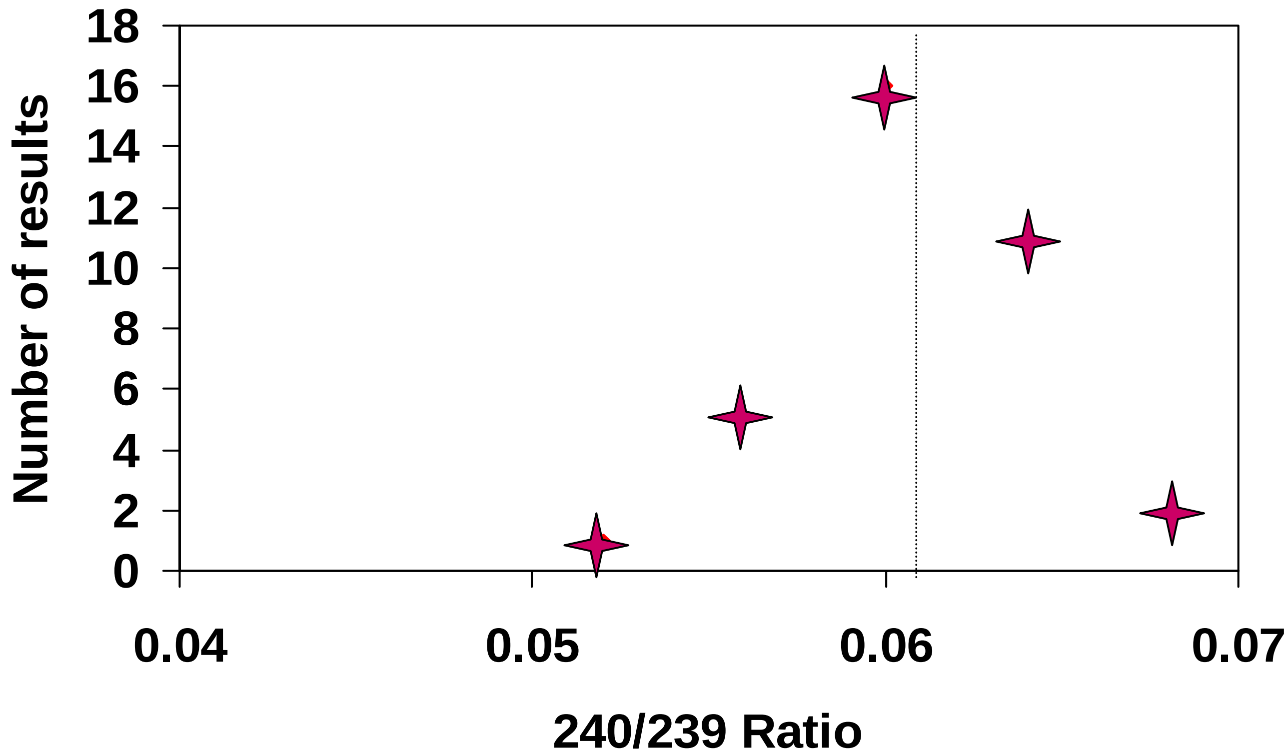
- Pu presence, isotopics, NMC measurements (all mature) provided correct results essentially 100% of the time.
- Occasional failures with γ oxide indicator:
  - peak sometimes missed owing to miscalibration; but
  - metallic samples were never misidentified as containing oxide.
- Symmetry algorithm analyzed data correctly at all times, but occasional errors arose owing to the distribution of Pu in the measured container.
- Relatively frequent failures to analyze age correctly.

Operating History after 15 Feb 2000

- Presence, NMC, isotopics continued to perform normally.
- Symmetry errors were greatly reduced by using a jig for aligning the samples.
- Oxide indicator failures much reduced (<5% of all measurements)
- Some age failures still persisted:
  - >90% success with "old" material; a few failures owing to electronics problems;
  - relatively frequent (~30%) failures on "young" material due to counting statistics.

This is the least mature technique at this time; the physics is in hand, but implementation would benefit from joint study.

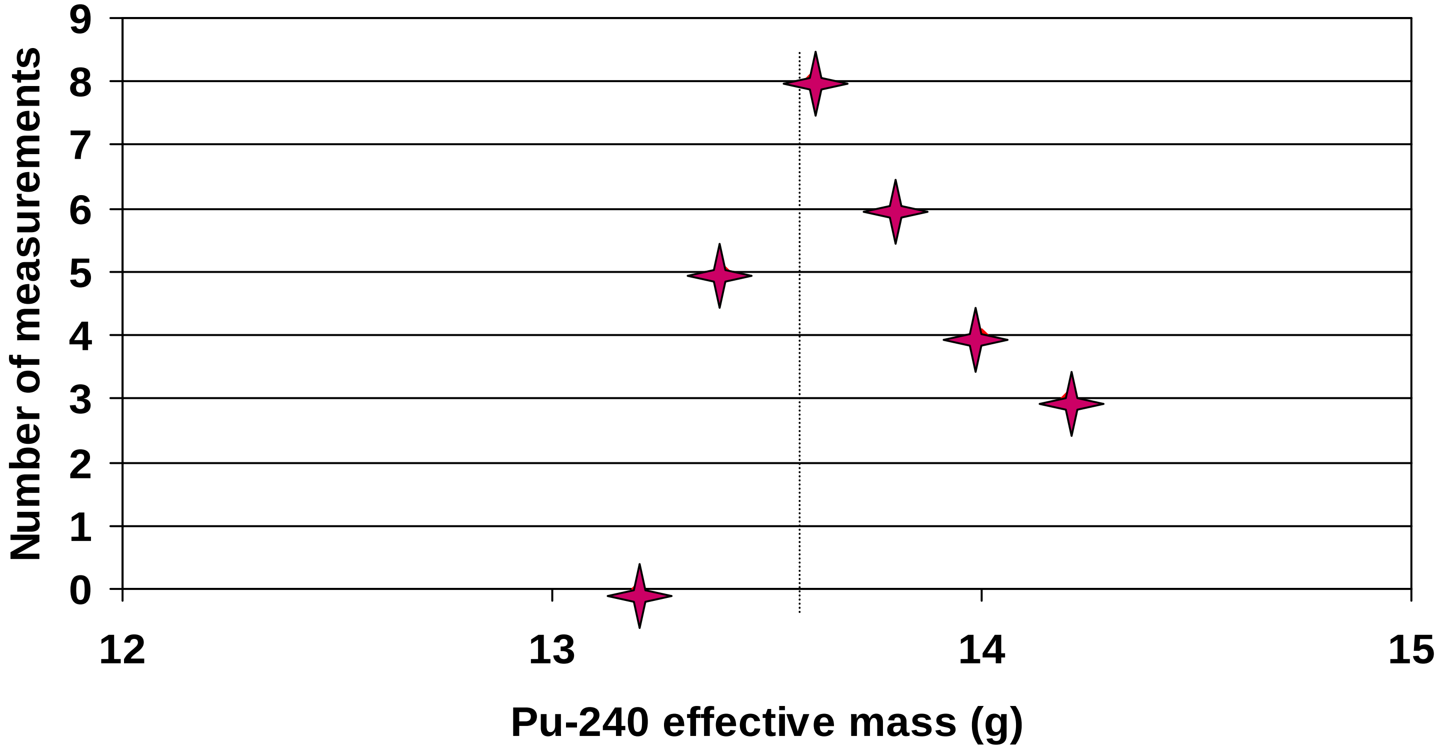
Isotopic Analysis and Statistical Error: Large Oxide Sample



Likelihood of a value is Gaussian about the true value, as measurement errors are purely statistical in nature.

Not All Measurement Error Is Purely Statistical in Nature

Example: Pu-240 eff. mass in ZPPR



Errors contain both statistical and systematic (sample location, etc.) components.

Lessons Learned

- The Attribute Measurement System with Information Barrier works, but R&D took longer than expected.
- The presence of the information barrier introduced unusual challenges to diagnosing problems that arose in the secure mode, when the system itself prevented us from accessing useful system data.
- <u>However: all system problems were eventually solved.</u>
- Spares and backups are crucial, as occasional electronics failures occurred even when the system was mature, as on any other advanced technology.
  - Authentication of spares and backups needs to be addressed in cooperative development.